

LETTER REPORT

Progress Report on An Investigation of Stress-Corrosion Cracking Susceptibility in Candidate Steels for Tension-Leg Platform Tendons

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Background: For the past several years, the Naval Research Laboratory (NRL) has been conducting a program to investigate the stress-corrosion cracking (SCC) susceptibility of candidate steels for tension-leg platform (TLP) tendons. This work has been conducted on behalf of the U. S. Coast Guard and the Minerals Management Service. Test materials for this program have been donated by Conoco Inc., Chevron Corporation and Nippon Steel U.S.A., Inc.

The use of high-strength steels in TLP tendons raises questions concerning the possibility of SCC occurring over long periods of time [1]. SCC is a type of spontaneous cracking which can develop slowly in many high-strength steels in a corrosive environment under the combined action of sustained tensile stress, which TLP tendons will experience, and exposure to seawater, which TLP tendons may suffer if corrosion protection systems deteriorate in service. If allowed to progress unchecked, SCC can potentially lead to catastrophic failure of a tendon.

A previous report [2], described SCC tests conducted on eleven high-strength steels provided by Conoco and Chevron. These previously reported steels included forging material, rolled plate and weld metal with yield strengths ranging from 80 to 125 ksi. This report describes further tests conducted on nine samples of high-strength steel weld metal, ranging in yield strength from approximately 80 to 130 ksi, provided by Nippon Steel U.S.A.

All testing in this program has been conducted in natural seawater at the NRL's Marine Corrosion Research Facility at Key West Florida. Fracture mechanics test methods have been used throughout the program [3,4]. In every instance, precracked bolt-loaded wedge-opening-loaded (WOL) specimens have been exposed to fresh flowing natural seawater for periods of one year or more. Specimens have been cathodically polarized to approximately -1.0 V versus Ag/AgCl by coupling to zinc anodes in order to simulate the potentially embrittling effects of cathodic protection.

Progress: The nine materials provided by Nippon Steel U.S.A. are described below. Nippon Steel provided NRL with 1-inch-thick 1-T WOL machined specimens of these materials.

<u>Plate</u>	<u>Yield Strength (ksi)</u>	<u>Ultimate Tensile Strength (ksi)</u>	<u>Chemical Composition</u>	<u>Weld</u>
A	≥80	≥95	1.2Ni-0.4Cr-0.3Mo-V	SAW
B	≥80	≥95	2.5Ni-0.5Cr-0.3Mo	SAW
C	≥128	not specified	5Ni-0.5Cr-0.5Mo-V	TIG

Specimens were tested at NRL-Key West for approximately 10,000 hours. Initial crack-tip stress-intensity (K_I) levels applied to these specimens varied from approximately 95 to 110 ksi/in. K_I values were estimated by using a crack-mouth-opening-displacement (CMOD) gage while loading. Some difficulties were encountered in precracking these specimens because of residual stresses inherent in weldments. Specific samples tested are described below.

<u>Identification</u>	<u>Plate</u>	<u>Precrack Location</u>	<u>Weld Condition</u>
AWD	A	Weld Metal	As Welded
AWF	A	Fusion Line	As Welded
ASD	A	Weld Metal	Stress Relieved
BWD	B	Weld Metal	As Welded
BWF	B	Fusion Line	As Welded
BSD	B	Weld Metal	Stress Relieved
BSF	B	Fusion Line	Stress Relieved
CD	C	Weld Metal	As Welded
CF	C	Fusion Line	As Welded

Upon completion of testing, specimens were broken open to examine the fracture surfaces for evidence of SCC. The only SCC observed was in specimen CD, i.e., the weld metal sample of the higher strength material. These specimens were loaded using internally strain-gaged bolts, which were used to record load changes during the course of testing. Measurements obtained from the strain-gaged bolt on specimen CD indicated that the load was diminishing with time, which is indicative of SCC crack growth. Figure 1 is a photograph of the fracture surface of specimen CD, showing the fatigue precrack, the area of SCC crack growth and the overload fracture resulting from breaking the specimen open.

Measurements of final load and crack depth indicate that the value of K_I at crack arrest for specimen CD, i.e., the K_{ISCC} value, is in the range of 35 to 50 ksi $\sqrt{\text{in}}$. In recent years, NRL has conducted extensive SCC testing of 130 to 150 ksi yield strength SMA, GMA and GTA weld metals [5]. For specimens coupled to zinc anodes, NRL data show a range of K_{ISCC} values for these weld metals of approximately 65 to 85 ksi $\sqrt{\text{in}}$. Thus, specimen CD exhibited somewhat greater susceptibility to SCC than would be expected from previous experience. However, it should be emphasized that the majority of materials studied in this investigation showed no susceptibility to SCC and thus are excellent candidate materials for offshore construction involving sustained tensile loading and exposure to a marine environment.

References:

- [1] T. W. Crooker and J. A. Hauser II, "Assessment Criteria for Environmental Cracking of High-Strength Steels in Seawater," NRL Memorandum Report 5035, March 8, 1983.
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- [3] *Characterization of Environmentally Assisted Cracking for Design: State of the Art*, National Materials Advisory Board, Publication NMAB-386, National Academy Press, Washington, D.C., 1982.
- [4] R. W. Judy, Jr., J. A. Hauser II and T. W. Crooker, "Influence of Experimental Variables on the Measurement of Stress-Corrosion Cracking Properties of High-Strength Steels," NRL Memorandum Report (pending).
- [5] C. T. Fujii, "The SCC Properties of Modified High-strength Steel Plates and Weld Metals," NRL Report 8325, July 17, 1979.

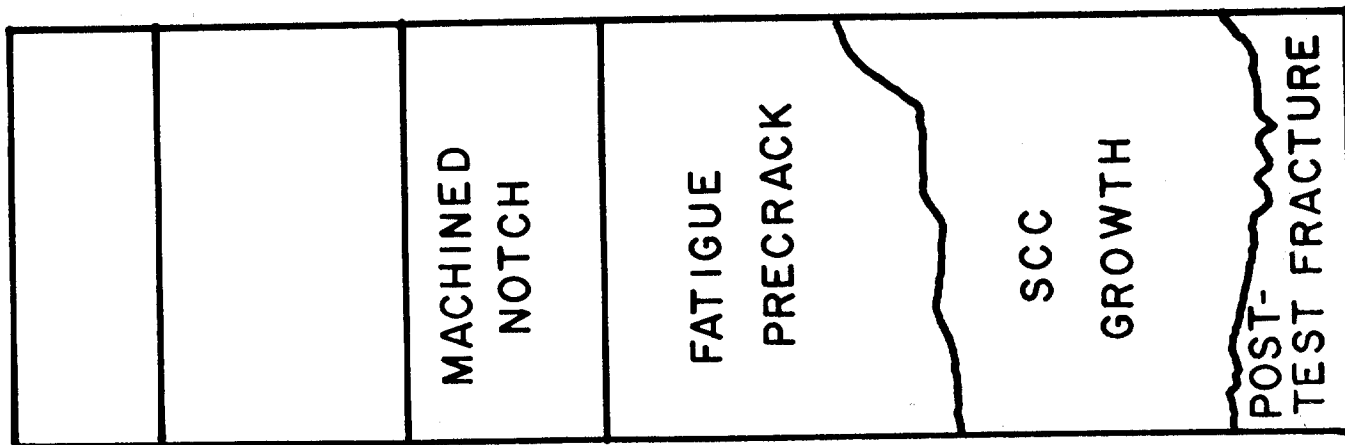


Figure 1 - Fracture surface of specimen CD.